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Attorney Docket No. 102314
18 Apr 14

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Filing Date	30 September 2013
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Attorney Docket No. 102314

ACOUSTIC-SENSING UNDERWATER TOW CABLE

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates generally to underwater tow cables, and more particularly to a cable that includes a cable core for transmission of power and data signals, a first jacket encasing the cable core, and discrete regions of carbon nanotubes (CNT) layers affixed to the first jacket and covered by a second jacket. The layers of carbon nanotubes at each of the discrete regions define an acoustic sensor. The positioning of the layers of carbon nanotubes provides specific acoustic information about the water column between the towing vessel and the towed sensor system as well as at other locations in the vicinity of the towed sensor system.

(2) Description of the Prior Art

[0004] Underwater surveillance is frequently performed using acoustic arrays/systems that are towed through the water. In general, these systems comprise a towing vessel, an electro-optical mechanical tow cable coupled on one end to the towing vessel, and a towed sensor system coupled to the other end of the tow cable. The towed sensor system includes an array of hydrophones designed to sense a variety of underwater acoustic signals based on a particular surveillance mission.

[0005] The sensor system is deployed at a generally horizontal orientation at some underwater depth as the tow cable traverses the distance/depth between the towing vessel and the towed sensor system. The tow cable provides the mechanical strength needed to tow the sensor system; the electricity required to power the sensor system; and for data signal transfer between the sensor system and the towing vessel. However, this type of acoustic surveillance system provides a limited amount of acoustic information about the water column between the towing vessel and the towed sensor system.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is a general purpose and primary object of the present invention to provide an acoustic-sensing underwater tow cable with the ability to provide detailed acoustic information about the water column between a towing vessel and a towed sensor system as well as at other locations in the vicinity of the towed sensor system.

[0007] Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

[0008] In accordance with the present invention, an acoustic-sensing underwater tow cable includes a cable core for transmission of power and data signals there along, a first jacket encasing the cable core, and discrete regions/layers of carbon nanotubes affixed to the first jacket. The CNT layers at each of the discrete regions define an acoustic sensor. At least one electrical conductor is coupled to each acoustic sensor. A second jacket encases each acoustic sensor and the electrical conductors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

[0010] **FIG. 1** is a prior art schematic view of a towed sensor system being towed by a vessel;

[0011] **FIG. 2** is a cutaway view of an acoustic-sensing underwater tow cable in accordance with an embodiment of the present invention;

[0012] **FIG. 3** is a side view of a carbon nanotube acoustic sensor region backed with acoustic isolation material in accordance with an embodiment of the present invention; and

[0013] **FIG. 4** is a cutaway view of an acoustic-sensing underwater tow cable construction in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Prior to describing the acoustic-sensing underwater tow cable of the present invention; reference is made to **FIG. 1** in which a surface-deployed vessel **100** tows a sensor array **102** in a horizontal orientation at some depth under the water surface **200.** As is known in the art, the sensor array **102** can be a hosed towed array or may be a rigid body equipped with wings, fairings, etc., (not shown) that maintain the proper towed body orientation during towing.

[0015] The sensor array **102** is mechanically and electrically (and/or optically) coupled to the towing vessel **100** via an electro-optical and mechanical tow cable **104.** The tow cable **104** includes strength members and data-carrying conductors/fibers as well as electrical power transmission wires.

[0016] Referring now to **FIG. 2,** an embodiment of an acoustic-sensing underwater tow cable construction in accordance with the present invention is shown and is referenced by numeral **10.** The tow cable **10** could be used to replace the above-described tow cable **104.** The tow cable **10** is illustrated in a cut-away view in order to illustrate the various portions thereof.

[0017] The central portion of the tow cable **10** is a cable core **12** that can include an outer jacket **120** disposed about a number of power and signal transmission lines **122.** Typically, the power and signal transmission lines **122** include one or more electrical conductors **122A** and one or more optical fibers **122B.** In addition to providing power, the transmission lines **122** support signal transfer between a towing vessel and a towed sensor system that would be coupled to either end of the tow cable **10.** The particular design of the cable core **12** is not a limitation of the present invention.

[0018] While the outer jacket **120** may provide sufficient mechanical strength for some (non-towing) applications, armor wires **14** are provided about the jacket. The particular type of the armor wires **14**, configuration, and size, are not limitations of the present invention. By way of non-limiting examples, the armor wires **14** include metal wires made from materials such as galvanized plow steel or synthetic fibers made from commercially-available materials such as KEVLAR or SPECTRA fibers.

[0019] Encasing the cable core **12** and armor wires **14** is a jacket **16** that extends along the length of the tow cable **10**. The jacket **16** is generally extruded in place. The jacket **16** is made from a flexible waterproof material such as polyurethane, nylon, or high-density polyethylene. The jacket **16** serves as the substrate for a number of relatively inexpensive acoustic sensors as will be explained further below.

[0020] In accordance with the present invention, acoustic sensors are defined on the jacket **16** by regions **18** of carbon nanotube (CNT) layers such as single-walled and multi-walled CNTs. In particular, research has shown that thin-film acoustic transducers may be built by using single-walled carbon nanotubes (SWNTs) that are thin, transparent, lightweight, durable and have an exceptional acoustic response.

[0021] More specifically, the regions **18** of CNTs are affixed to the jacket **16**. Each region **18** is a thin layer of CNTs that can be sprayed or rolled on masked-off regions of the jacket **16**, or affixed to the jacket via film transfer techniques. The well-known electrical properties of CNTs allow each region **18** to function as an acoustic sensor or hydrophone. The size/shape of the region **18** can be used to tune the region for sensitivity to specific acoustic frequencies.

[0022] For example, sensitivity to lower frequencies could be achieved by increasing the size/length of the region **18** along the tow cable **10**. Each region **18** of CNTs has one or more electrical conductors **20** coupled thereto with conductors extending back along the length of the cable **10** to the end thereof that is to be coupled to a towing vessel. The number of conductors **20** may be optimized by using electrical signal techniques such as multiplexing.

[0023] Encasing the regions **18**, the conductors **20**, as well as exposed portions of the jacket **16**, is another waterproof jacket **22**. The jacket **22** can be similar to the jacket **16** in that it can be extruded in place and can be made from polyurethane, nylon, or high-density polyethylene.

[0024] The advantages of the present invention are numerous. Since a conventional underwater tow cable typically includes a cable core **12**, armor wires **14** and a jacket **16**; the conventional underwater tow cable can be readily modified to incorporate a number of CNT-region acoustic sensors. In this way, an underwater tow cable can provide acoustic information within the water column between a towing vessel and a towed sensor system as well as other locations in the vicinity of the sensor system.

[0025] Although the present invention has been described relative to a particular embodiment thereof, the scope of the present invention is not so limited. For example, as shown in **FIG. 3**, each region **18** of CNTs could be disposed on a layer of acoustic isolation material **24**. The goal of the isolation material **24** is to isolate the region **18** from mechanical vibrations emanating from the cable core **12** and the armor wires **14**. The isolation material **24** can be an acoustic isolation material (e.g., rubber, nylon, or polyurethane) that is applied prior to affixing the regions **18** or simultaneously with the regions.

[0026] **FIG. 4** illustrates another embodiment of the present invention where a layer **26** of CNTs are affixed to the jacket **16** along the length thereof in such a way that the discrete regions **18** are still defined while the layer **26** covers the remainder of the outer surface of jacket. That is, a CNT-free gap **28** surrounds each CNT region **18**. Each gap **28** can be defined by masking the jacket **16** prior to the affixing of CNTs thereto. As a result, the regions **18** still function as acoustic sensors while the remaining contiguous CNT layer **26** provides additional mechanical strength for the core of the tow cable **10**.

[0027] It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

ACOUSTIC-SENSING UNDERWATER TOW CABLE

ABSTRACT OF THE DISCLOSURE

An acoustic-sensing underwater tow cable includes a cable core for transmission of power/signals there along, a first jacket encasing the cable core, and discrete regions of carbon nanotubes affixed to the first jacket. The carbon nanotubes at each of the discrete regions define an acoustic sensor. A second jacket encases each acoustic sensor and any electrical conductors coupled thereto.

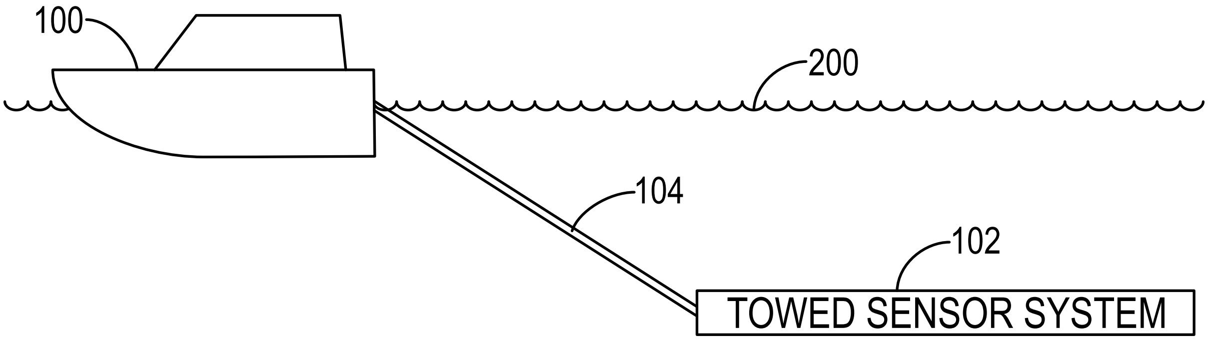

FIG. 1
(PRIOR ART)

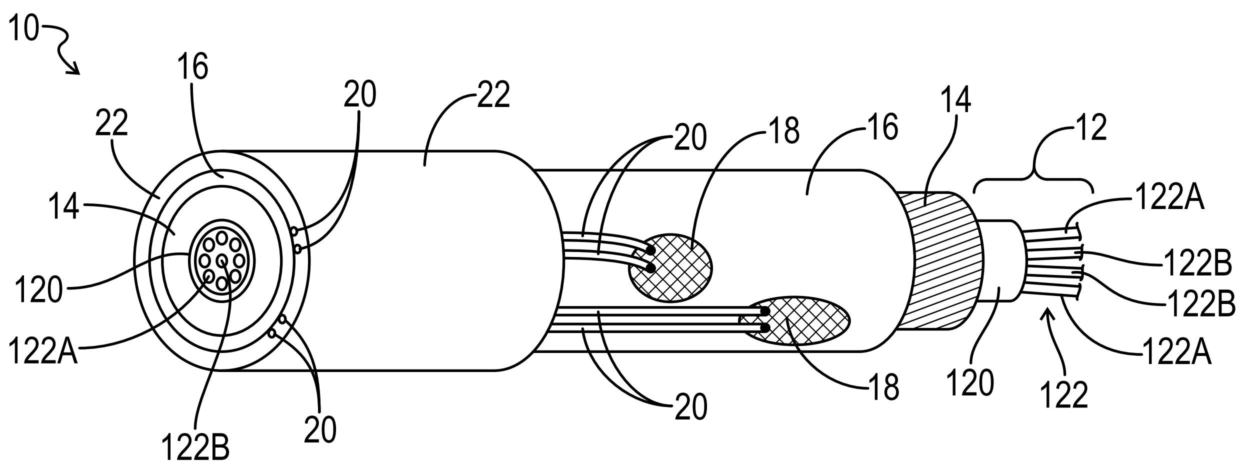

FIG. 2

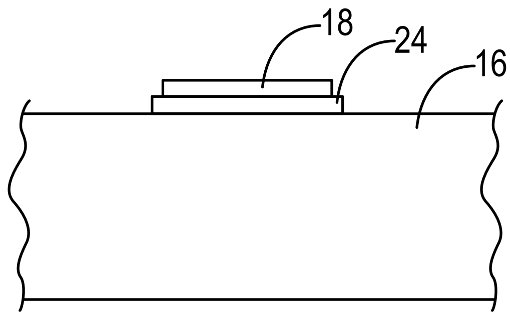

FIG. 3

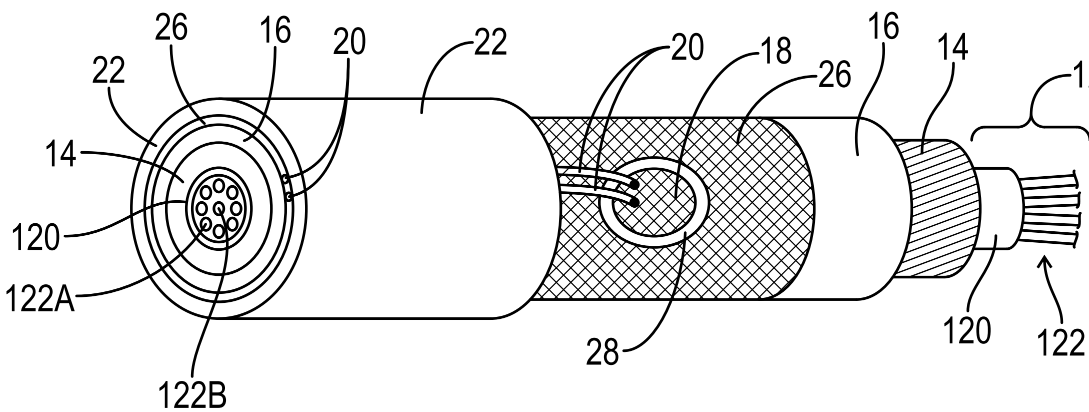

FIG. 4